

# Cold Dark Matter Halos Must Burn

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**Abstract.** High-quality optical rotation curves for a sample of low-luminosity spirals evidence that the dark halos around galaxies are inconsistent with the output of proper CDM simulations. In fact, dark halos enveloping stellar disks are structures with approximately a constant density out to the optical edges. This is in strong disagreement with the characteristic  $\rho(r) \propto r^{-1.5}$  CDM regime and severely challenges the “standard” CDM theory also because the halo density appears to be heated up, at gross variance with the hierarchical evolution of collision-free particles.

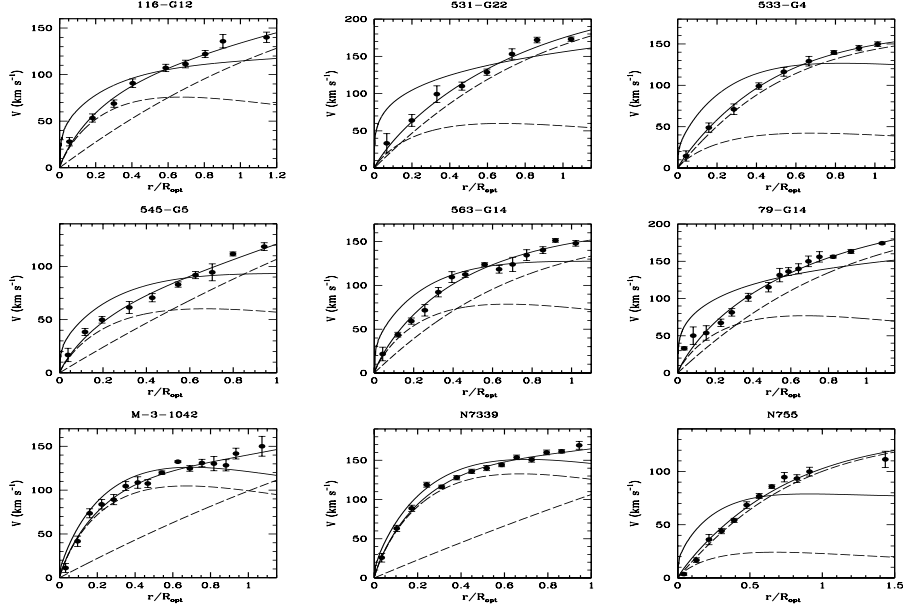
## 1 CDM and Galaxy Halos

Dark matter (DM) halos in the Cold Dark Matter scenario are formed via dissipationless hierarchical merging and harbor the infall/cooling of the primordial gas that leads to the formation of the present-day galaxies. Several studies have investigated the detailed structure of these halos by means of  $N$ -body simulations at a progressively higher spatial/mass resolution (e.g. [1], [2]). The outcome is well known: CDM halos have an “universal” profile in their density which includes a steep central cusp. In detail, on galactic scales  $\simeq 1 - 10$  kpc:  $\rho(r) \propto r^{-\gamma}$ . Simulations at the highest resolution indicate  $\gamma = -1.5$  [3].

Name	$M_I$	$R_{\text{opt}}$	$\beta$	$\rho_s$	$r_s$
116-G12	-20.0	5.4	$0.29^{+0.03}_{-0.1}$	$2.7^{+3}_{-0.7}$	$10^{+10}_{-5}$
531-G22	-21.4	10.5	$0.11^{+0.07}_{-0.06}$	$2.1^{+0.5}_{-0.4}$	$12^{+4}_{-2}$
533-G4	-20.7	8.4	$0.07^{+0.05}_{-0.02}$	$4.3^{+0.5}_{-0.9}$	$6^{+2}_{-1}$
545-G5	-20.4	7.5	$0.21^{+0.03}_{-0.03}$	$1.0^{+0.3}_{-0.3}$	$22^{+300}_{-4}$
563-G14	-20.5	6.3	$0.25^{+0.02}_{-0.07}$	$4.3^{+1}_{-0.9}$	$6^{+2}_{-2}$
79-G14	-21.4	12.3	$0.19^{+0.03}_{-0.07}$	$1.3^{+0.3}_{-0.3}$	$14^{+4}_{-2}$
M-3-1042	-20.1	4.7	$0.45^{+0.06}_{-0.04}$	$2.2^{+3}_{-0.8}$	$15^{+300}_{-10}$
N7339	-20.6	4.9	$0.53^{+0.05}_{-0.03}$	$2.1^{+0.3}_{-0.5}$	$22^{+300}_{-7}$
N755	-20.1	4.8	$0.05^{+0.02}_{-0.04}$	$4.1^{+1}_{-0.7}$	$5^{+3}_{-1}$

Let us represent generic halos, including the CDM ones, by means of:

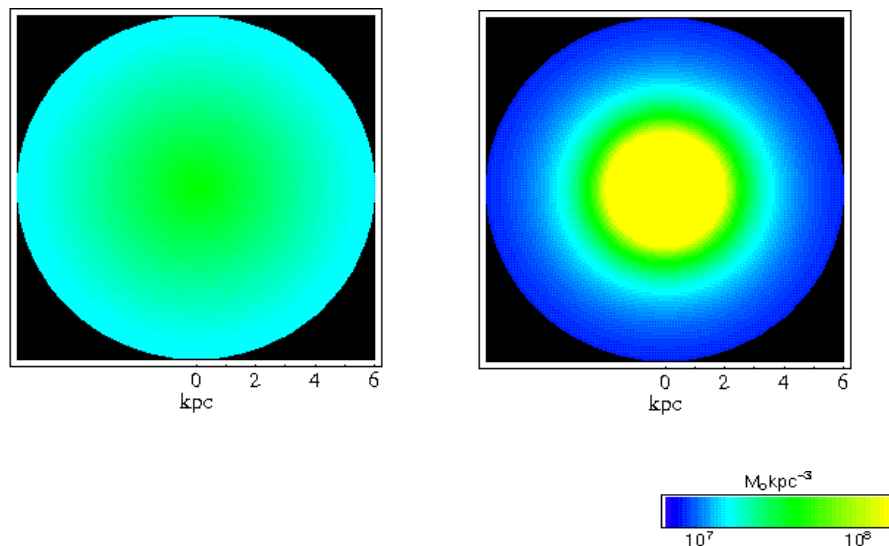
$$\rho(r) = \frac{\rho_s}{[c + (r/r_s)^\gamma] [1 + (r/r_s)^\alpha]^{(\delta-\gamma)/\alpha}} \quad (1)$$



**Fig. 1.** RC's of the sample (*points*) vs CDM model (*discrepant continuous line*) and vs BS model, of which the disk and halo contributions are shown as (*dotted lines*).

where  $\gamma$  is the density inner slope,  $\delta$  is the outer slope and  $\alpha$  settles the turnover point between the inner and outer regimes. The parameter  $c$  indicates the presence of a “constant density” (inner) region (CDR). If  $c = 0$ , as in collisionless CDM, the density diverges for  $r \rightarrow 0$ . In the case of  $c = 1$ ,  $r_s$  is the size of the CDR, whose value is  $\rho_s$ . According to the above notation, the Moore density profile corresponds to  $(c, \alpha, \delta, \gamma) = (0, 1.5, 3, 1.5)$  and the Burkert–Salucci one to  $(1, 2, 3, 1)$  [4].

We test these mass models by means of the dark halos detected around galaxies of a sample of low luminosity late-type spirals. In these objects the DM distribution can be easily derived from the available high-quality *optical* rotation curves because the stellar and HI disks contribute very little to the gravitational potential so as the beam smearing effect, plaguing the HI RC's, is obviously absent. The sample includes 9 high-quality *optical* RC's that are smooth and symmetric and extend at least out to the optical edge  $R_{opt}$ . The characteristics of merit are the following: the spatial resolution is better than  $1/20 R_{opt}$  and the velocity *rms* is  $< 3\%$ . The mass modeling is furthermore simplified in that in these spirals the gas contribution to  $V(r)$  (for  $R < R_{opt}$ ) is modest [5] and the stellar surface brightness is very well fit by a Freeman disk.



**Fig. 2.** *left*) Dark halo around 116-G12, *right*) CDM prediction for a halo of the same mass (inside  $R_{\text{opt}}$ ).

## 2 The Structure of Dark Halos

The mass model includes *i*) a stellar exponential thin disk with free parameter  $\beta \equiv (V_D/V)_{R_{\text{opt}}}^2$  i.e. the fractional disk contribution to the total circular velocity at  $R_{\text{opt}}$ , and *ii*) a dark spherical halo, whose contribution to  $V(r)$  is obtained from (1) in that:  $V_h^2(r) \equiv \frac{G}{r} \int_0^r 4\pi r'^2 \rho(r') dr'$ . Once we choose the scenario (i.e.  $c = 1$  or  $c = 0$ ), we are left with two free parameters,  $\rho_s$  and  $r_s$ , the characteristic density and radius. Both get determined by adjusting the model to data as in [5].

The CDM halo profiles fail: in no case they can reproduce (with or without an exponential disk) the observed RC's. This is shown in Fig. 1: the discrepancy with data is very high at any radius. The CDM halos, even allowed to take any value for  $r_s$  (or for the concentration parameter), have definitely a too steep density profile in the innermost region and show a too flat profile in the outer regions.

Next, we fit the BS profile to the data: the results are shown in Fig. 1 and Table 1. This model fits perfectly, indicating the values of parameters which are reported in Table 1. Each of 9 halos has a central density  $\rho_s$  of about  $1-4 \times 10^{-24}$  g/cm<sup>3</sup> that keeps constant out the edge of the stellar distribution.

### 3 You Don't Need More Evidence

We definitely conclude, as in [5], that the dark halos embedding the stellar disks show a density distribution inconsistent with that predicted by CDM (see Fig.2). Real halos in the Universe rather resemble, in the regions where the stars reside, some homogeneous spheres. Crucially, the sample and the method employed here level off to zero the criticisms raised to previous claims for DM core radii in galaxies. Furthermore, since the DM radial distribution out to  $R_{opt}$  is featureless, we cannot link together the local and the global properties of the dark halos; such a connection, which is a main consequence of the bottom-up merging scenario appears to be just missing in Nature. The CDM scenario, then, must find a way to cut off any signature of the gravitational collisionless collapse. For instance, the “temperature” of the CDM particles, which initially  $\rightarrow 0$  for  $r \rightarrow 0$ , must be largely heated up and kept constant out to the disk edge (see [6]). Solving this deep mystery will be the guideline of our (and others) future research.

### References

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